NSSL
Modeling and Assimilation Program

- **Talk Contributors**
  - Dusty Wheatley (CIMMS)
  - Nusrat Yussouf (CIMMS)
  - Dan Dawson (NRC Post-Doc)
  - Jidong Gao (Fed)
  - Ted Mansell (Fed)
  - Thomas Jones (CIMMS)

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Modeling and Assimilation Program

- **2010 Deliverables**
  - Completion of VORTEX2 field phase data collection activities.
  - Quality controlled and supplemental data sets for 5 June 2009 VORTEX2 case
  - Summary report for automated radar QC
  - Report on the CAPS real-time 3DVAR with assessment of system by forecasters and archive of results.
  - New federal scientist hired to assist in data assimilation activities.
  - Warn-on-forecast webpage completed and online.
  - Other deliverables to be discussed elsewhere

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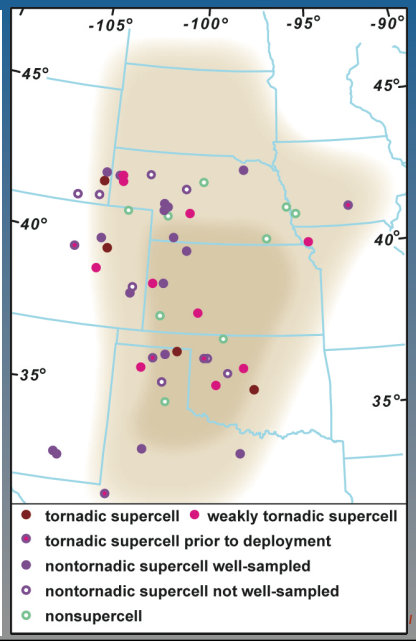
VORTEX2 2009 & 2010

WoF VORTEX-2 Participants

Mansell, Wicker, Knopfmeier, Thompson, Sobash, Manross, Potvin, Dawson

- 82 Field Days
- >35,000 miles driven
- ~15 Tornadic Supercells
- ~18 Supercell Tornadoes
- ~29 Nontornadic Supercells
- ~7 QLCSs
- ~2 QLCS Tornadoes
- 10-15 TB of data?
- All in situ data has to be QC'd
- Radar data (>20,000 PPIs?)
  - orientation of radar to < 0.2 deg
  - clutter filtering
  - dealiasing of radial velocity, attenuation correction



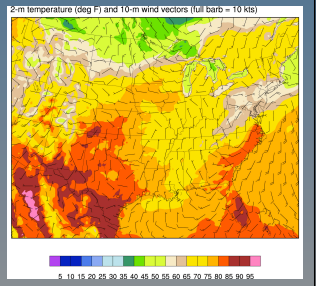
Our Two Approaches

- **Top Down**
  - **mesoscale ensembles** creating analyses at lower resolution (~20 km)
  - use multi-sensor data (surface, satellite, acars...)
  - useful for 0-6 hour severe weather threat assessment
  - then used to provide IC/BCs for high-res storm-scale
- **Bottom Up**
  - **storm-scale** modeling to develop and test algorithms for radar data assimilation (~ 1 km).
  - focused on optimal use of radar data
  - used to reduce impact of model error on DA
  - homogeneous experiments are then scaled up to full multiscale

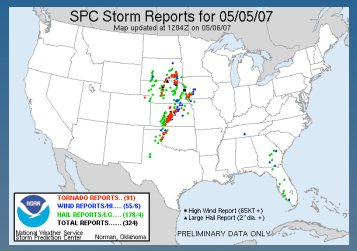
WRF Mesoscale Ensemble DA System

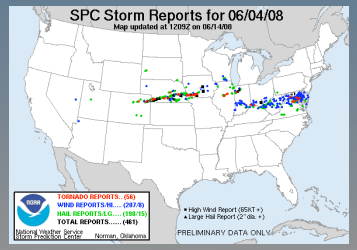
(D. Wheatley & N. Yussouf)

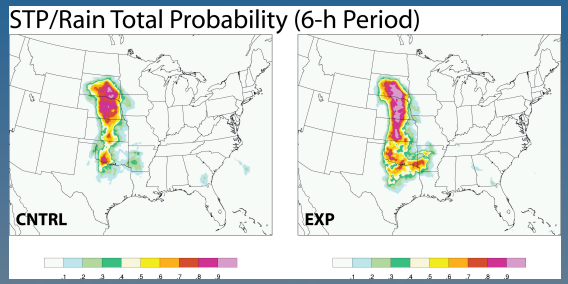
- WRF (ARW)
  - Eastern two-thirds of CONUS
  - 20-km horizontal grid spacing; 51 vertical levels
  - Mean initial and boundary conditions from the NAM forecast cycle starting at 1200 UTC
- 36-member ensemble
  - IC/BC perturbations for WRF-Var
  - Physics diversity
- Data Assimilation Research Testbed (DART)
  - Ensemble Kalman filter (EnKF) approach
  - p (land-surface altimeter), T, T_d, u, v
    - Land and marine surface stations
    - Radiosonde
    - Automated aircraft

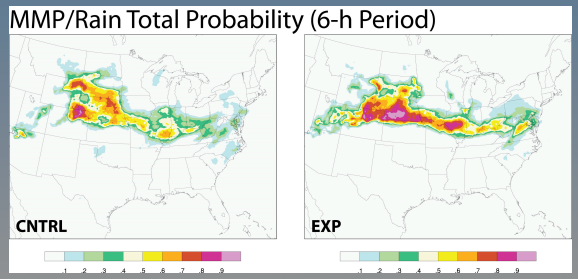


EnKF forecasts of 24 prolific severe events from springs 2007-2009 suggest improved ensemble forecast products during the 0-6 h forecast period





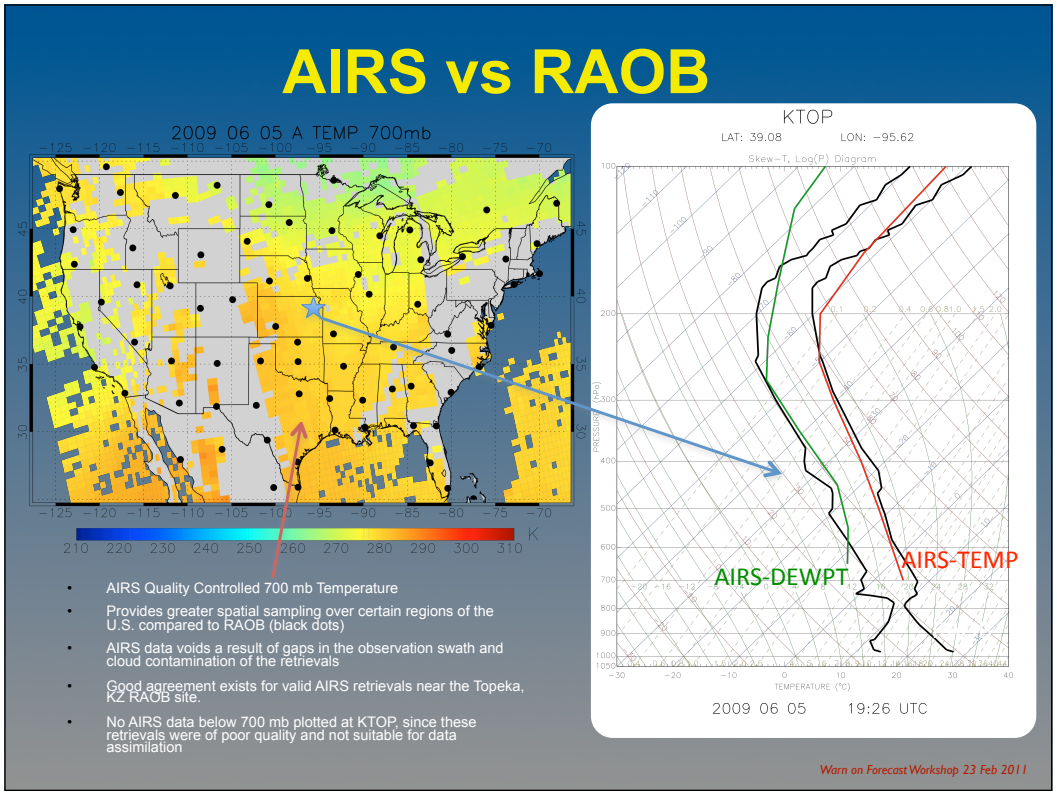




Satellite Data Assimilation

(T. Jones)

- **GOAL:** Use satellite data to improve short term meso-scale and storm-scale WRF forecasts
- **Satellite Data Examples:**
  - Temperature and humidity profiles
  - Cloud microphysical properties
  - Microwave, infrared, and visible spectrum radiances / reflectance
- **Assimilate AIRS temperature and humidity profiles into WRF-DART**
  - AQUA polar orbiting satellite: two overpasses per day
  - Provides temperature and humidity retrievals at mandatory pressure levels at a ~45 km horizontal resolution



- Sampling location changes each day as a function of orbit and cloud conditions
- The more clouds, the greater uncertainty in retrievals

Future Work: Satellite

- Run nested grid (Dx = 3 km) to determine effect of AIRS data on forecasting significant events.
- Repeat current analysis with new high-resolution (15 km) AIRS product produced by CIMSS in Wisconsin
- Longer term, move on to direct assimilation of visible reflectances from GOES.
  - Improve analysis of cloud characteristics within model
  - Primary goal of improving convective initiation forecasts
  - Summer 2011 onward

Storm-scale DA

- Focused on real data cases
- Storm-scale 3DVAR real-time analyses
  - showing analyses to OUN forecasters
- Research mode: technique development
  - Greensburg KS 2007 (F5 tornadic storm)
  - Moore OK 2003 (F4 tornadic storm)
  - Lagrange WY 2009 (VORTEX2 case)
- Other synergistic activities
  - Use of 2 & 3 moment microphysics
  - Impact from PAR data
  - Assimilation resolution studies

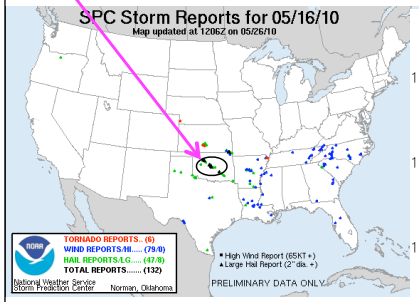
Storm-scale 3DVar Development & Applications
(J. Gao)

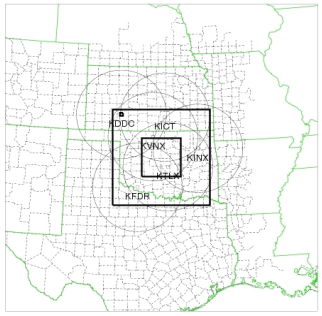
- Real-time analysis: Demonstrated near real-time, weather-adaptive and users on-demand 3DVAR analysis at 1 km resolution – ingesting mainly WSR-88D data (Stensrud et al. 2010).

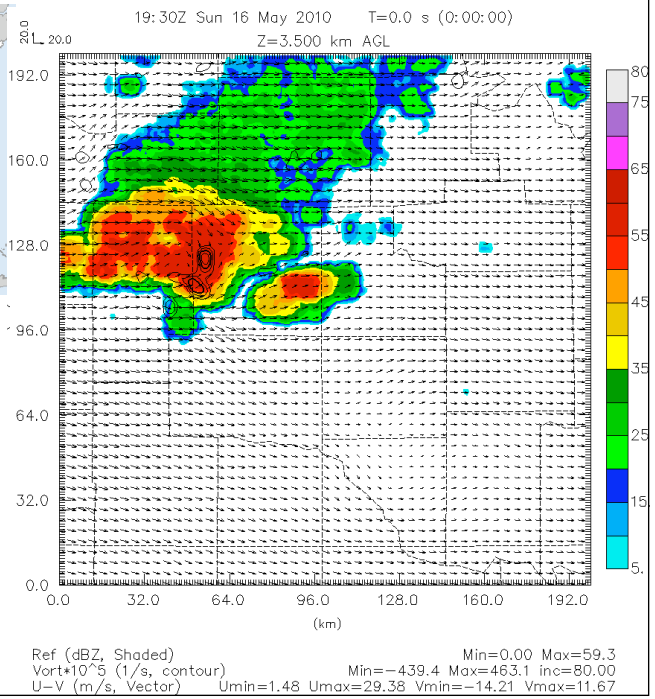
- Reflectivity Data Assimilation: Finished some preliminary tests directly assimilating reflectivity data with a unified 3DVAR framework.

- Preliminary Hybrid 3DVAR-EnKF development: with idealized dataset (in collaboration with CAPS).

May 16th OKC metro Hailstorm

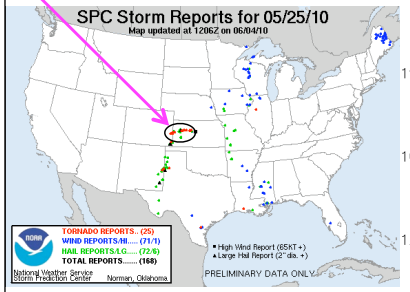


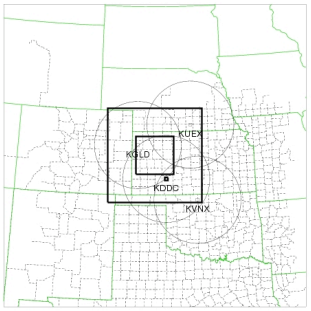


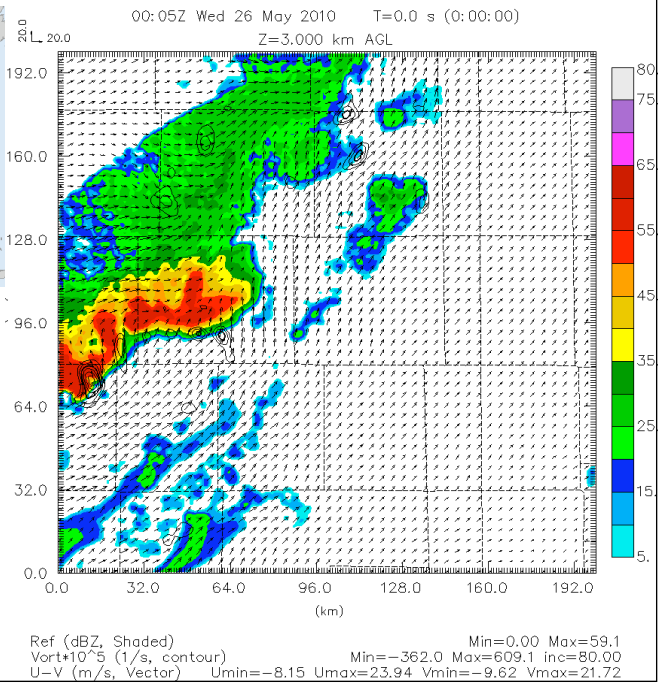


Ref (dBZ, Shaded) Min=0.00 Max=59.3
Vort*10^5 (1/s, contour) Min=-439.4 Max=463.1 inc=80.00
U-V (m/s, Vector) Umin=1.48 Umax=29.38 Vmin=-14.21 Vmax=11.67

V2 Case: 25 May NW KS Tornadoes







Ref (dBZ, Shaded) Min=0.00 Max=59.1
Vort*10^5 (1/s, contour) Min=-362.0 Max=609.1 inc=80.00
U-V (m/s, Vector) Umin=-8.15 Umax=23.94 Vmin=-9.62 Vmax=21.72

Assimilating reflectivity within a variational framework

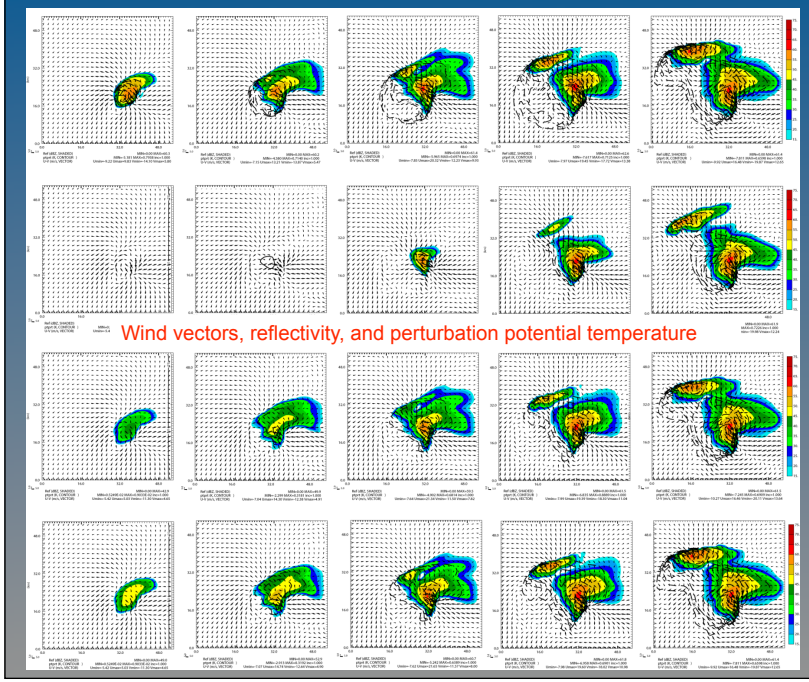
- First method (1)
  - total reflectivity computed as (Smith 1975);

$$Z_e = Z_{er}(q_r) + Z_{es}(q_s) + Z_{eh}(q_h), \qquad (1)$$

- Second method (2)
  - partition reflectivity via temperature
    - T > +5 C: all rain
    - T < - 5 C: all snow and hail
    - 5 C > T > -5 C: mixed phase
      - linearly partition reflectivities between rain and snow/hail

$$Z_e = \begin{cases} Z_{er}(q_r) & T_b > 5^o C \\ Z_{es}(q_s) + Z_{eh}(q_h) & T_b > -5^o C \\ \alpha Z_{er}(q_r) + (1-\alpha)\left[Z_{es}(q) + Z_{eh}(q)\right] & -5^o C < T_b < 5^o C \end{cases} \qquad (2)$$

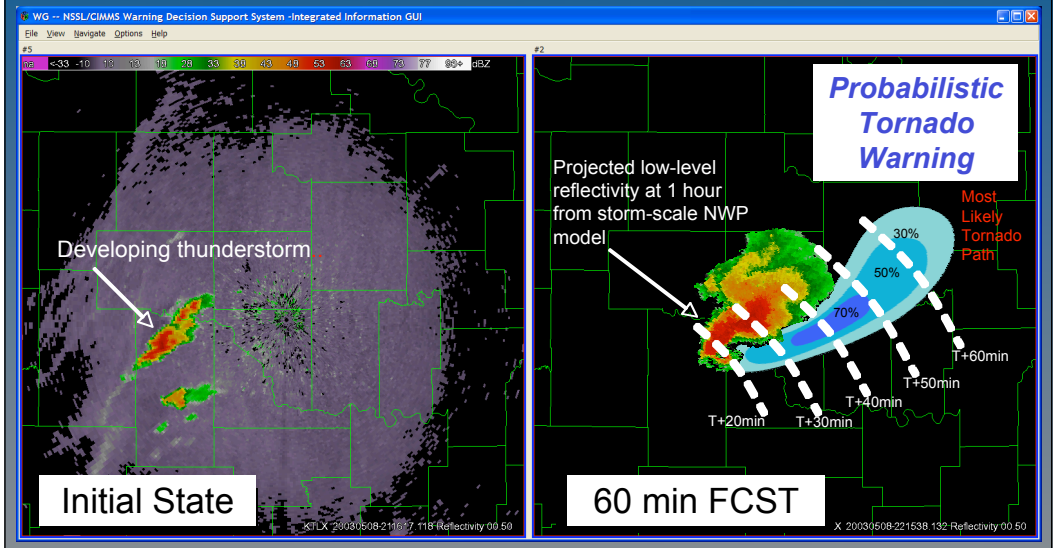
3DVAR OSSE


0 min
10 min
20 min
30 min
40 min
Truth
Vr alone
Wind vectors, reflectivity, and perturbation potential temperature
Vr & Z with (1)
Vr & Z with (2)

Future Work

- **Real-time storm-scale analysis:**
  - Continue real-time, 3DVAR analysis at 1 km resolution
  - ingest surface Mesonet data in addition to other datasets.
- **Real-time forecasts using 3DVAR Initialization:**
  - 1440x1440 km domain over central/southern Plains (dx=3km)
  - Work with Norman NWS WFO - 6 hour forecasts launched every 1 hour
  - Assimilate NEXRAD data and surface observations (including mesonet data)
- **Thermodynamic constraint & Reflectivity Data Assimilation:**
  - Demonstrate impact of new constraints
- **EnKF & 3DVAR:**
  - Compare performance of 3DVAR and EnKF for storm-scale NWP.
  - Continuing Hybrid EnKF and 3DVAR work.

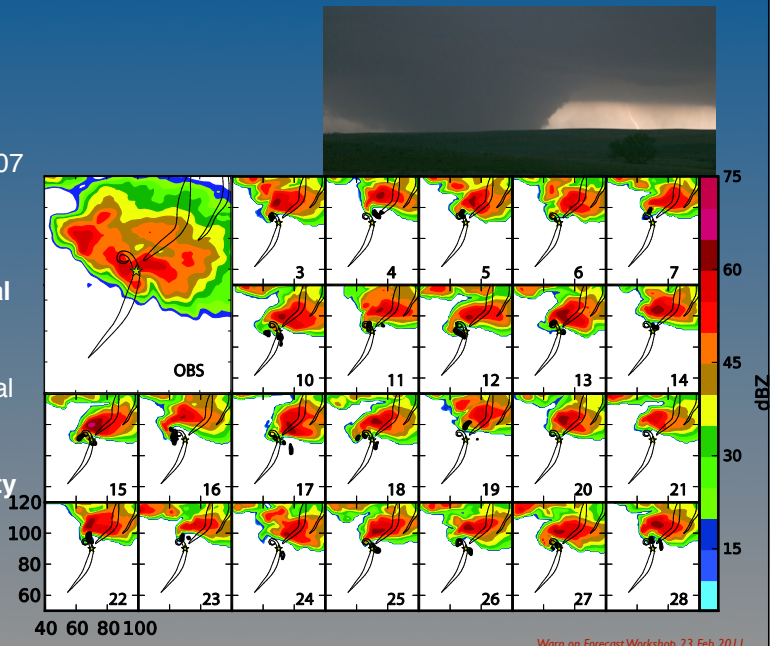
The WoF Vision



Greensburg KS (2007)

D. Dawson, L. Wicker, T. Mansell, R. Tanamachi

- **EnKF analysis and prediction** of the significant tornadic storm on 5 May 2007 storm near Greensburg, KS
- **Single radar retrival** using DDC obs
- **Homogeneous** initial environment
- Examined **sensitivity to low-level wind profile** and (to a lesser extent) microphysics



Probabilistic Vorticity Forecast

(All 9 experiments)

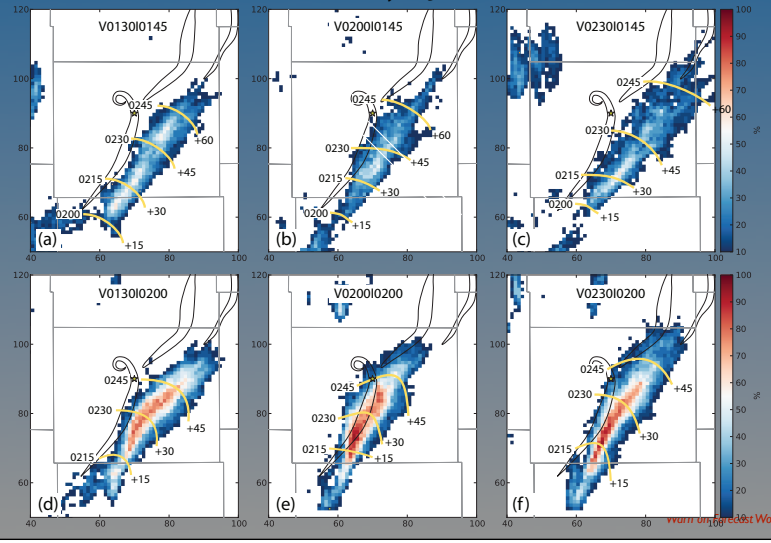
Initial VAD Profile (UTC)

0130 **0200** **0230**

Ensemble Probability of $\zeta > 0.01\ s^{-1}$ (75 m AGL)

60 min forecasts

45 min forecasts



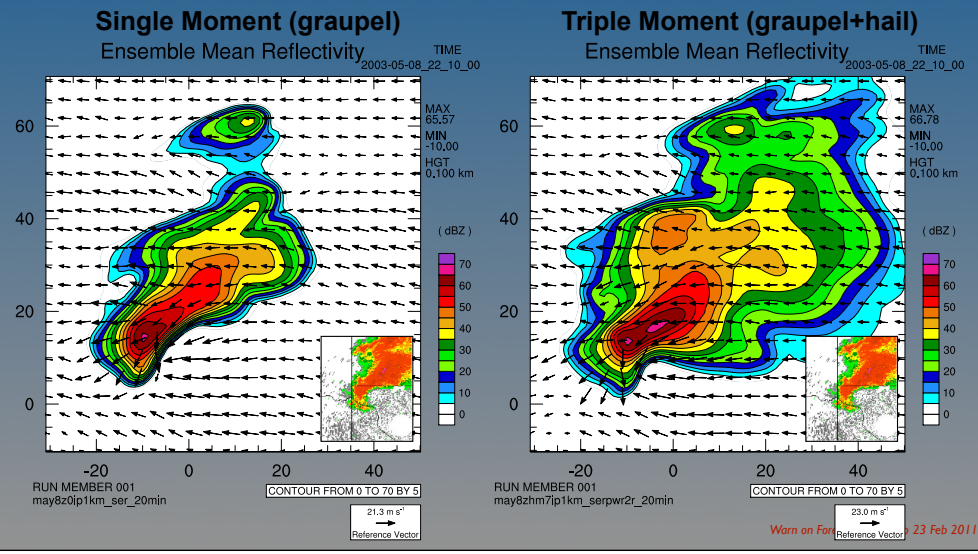
Microphysical Parameterization Development

(T. Mansell, D. Dawson)

- Development of 3-moment microphysical scheme suitable for deep convection
- Testing of 3-moment scheme within EnKF framework
- Verification of microphysical parameterizations
  - using dual-polarization radar data
  - forward operator from Y. Jung and M. Xue
  - collaboration with CAPS

8 May 2003 @ Tornadogenesis
Mean Reflectivity at 1 km

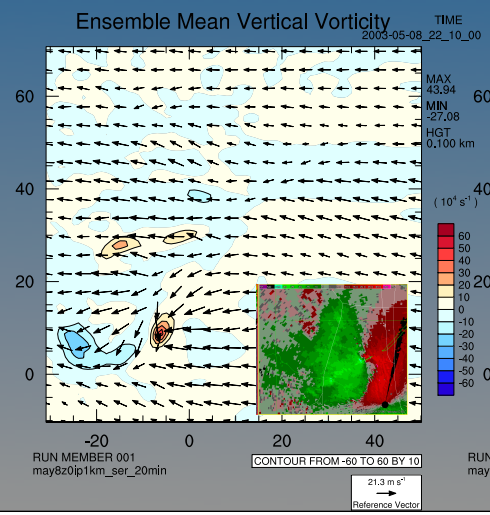
20 min. forecasts, valid 22:10 UTC (8 May 2003)



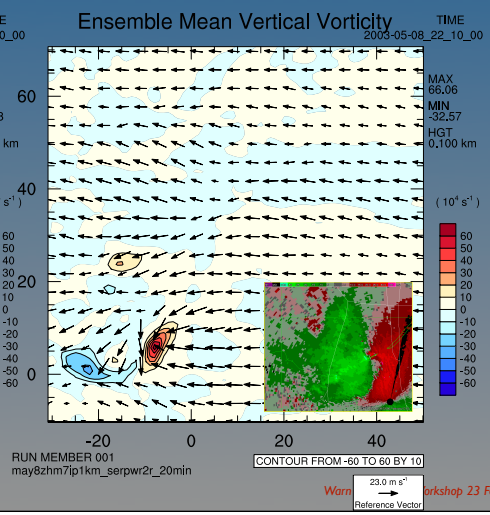
8 May 2003 @ Tornadogenesis
Mean Vorticity near SFC

20 min. forecasts, valid 22:10 UTC (8 May 2003)

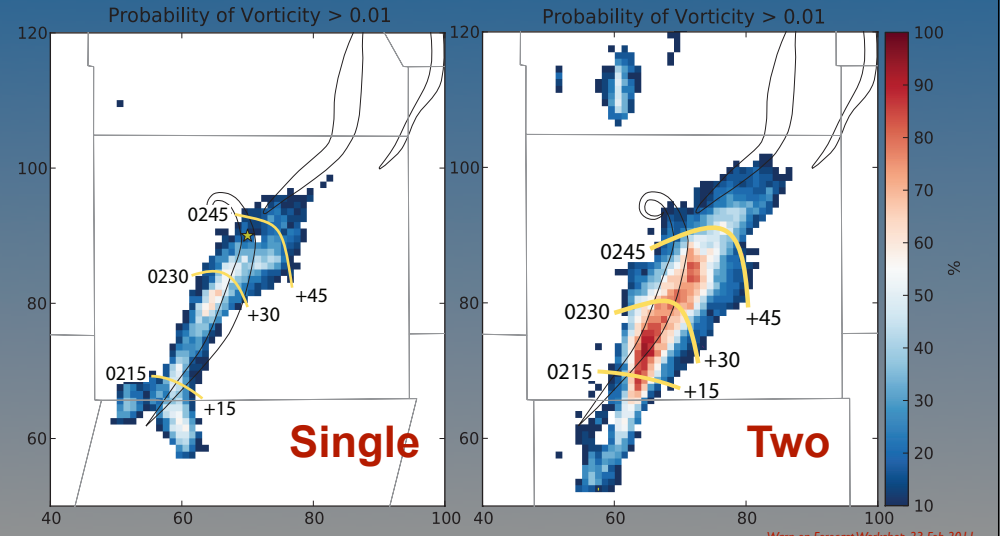
Single Moment

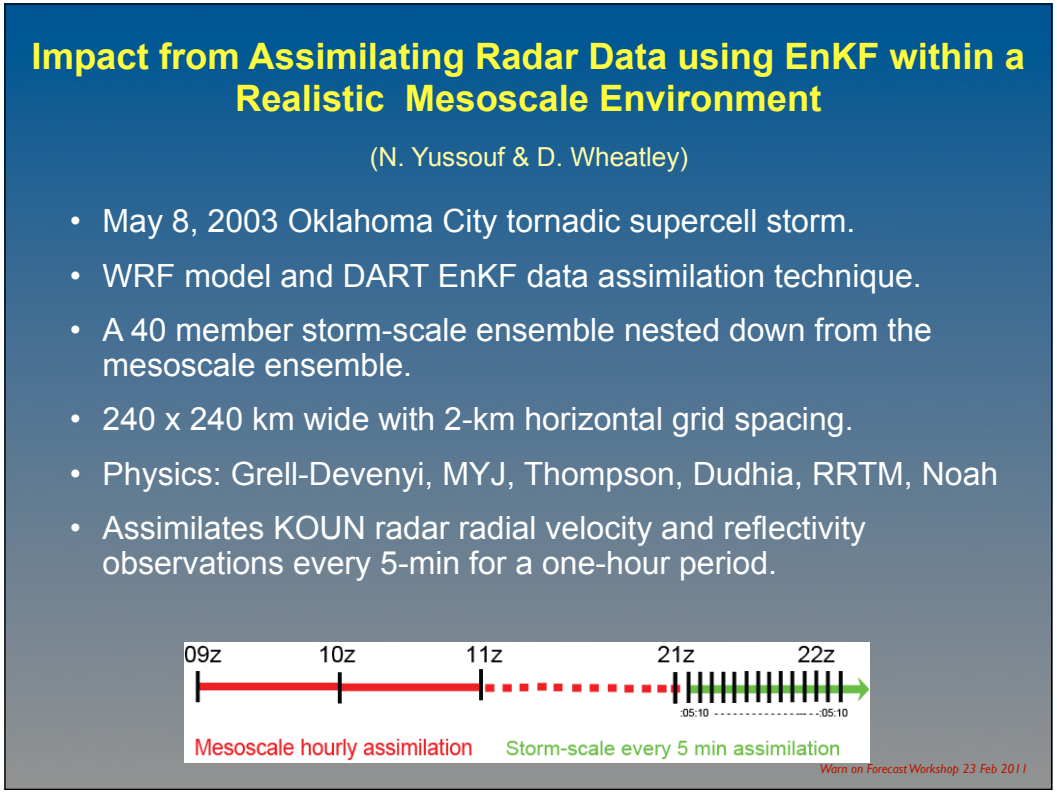


Triple Moment



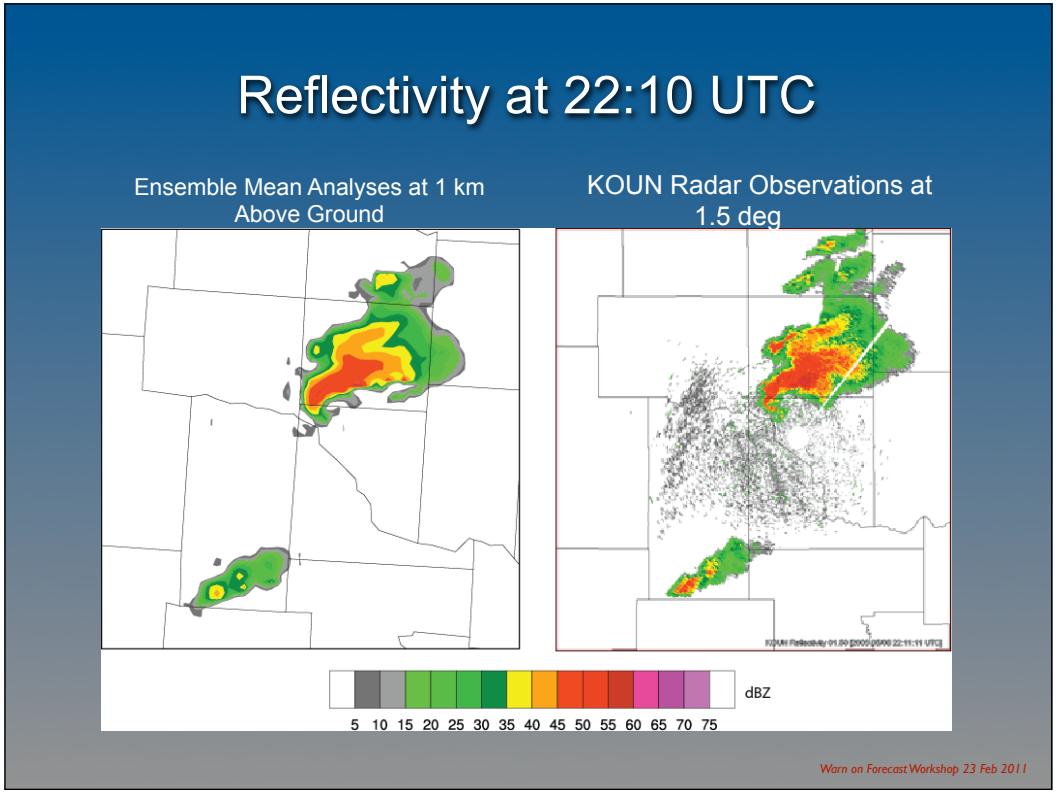
Is Microphysics Important?
Greensburg KS Forecasts
Single vs. Two Moment Microphysics



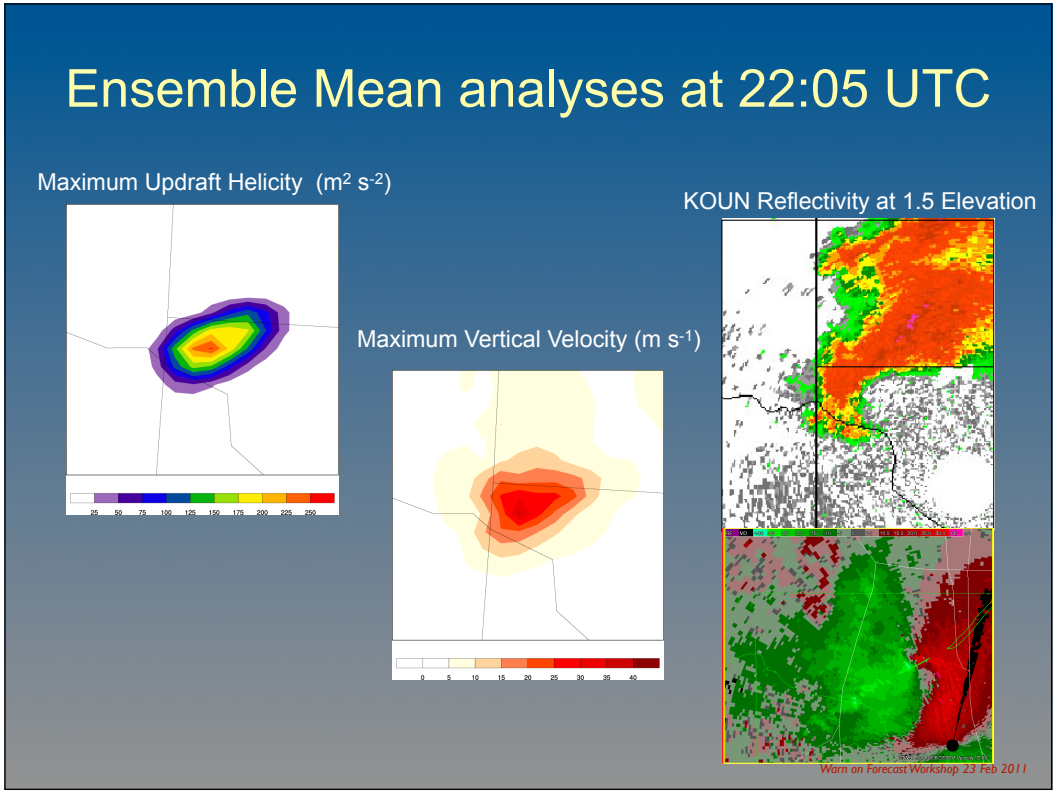


Lanuched a stormscale ensemble nested down to 2 km from a 20-km horizontal grid spacing mesoscale WRF/DART ensemble. Routinely available observations from metar, radiosonde, marine and ACARS observations are assimilated in the mesoscale ensemble on an hourly basis for a 12 h period, and this mesoscale ensemble is used to create the initial and boundary condition for the storm-scale ensemble. Assimilated KOUN reflectivity and radial velocity observations every five minutes for a one hour period. During the one hour assimilation period, 14 volume scans of radar observations are assimilated.

Figure: Hourly mesoscale assimilation starts at 09:00 UTC and ends at 21:00 UTC. Every 5 minutes storm-scale assimilation starts at 21:05 UTC and ends at 22:10 UTC.



On the left is the ensemble mean reflectivity analyses at 1 km above ground at the last assimilation cycle. On the right is the KOUN reflectivity observations at 1.5 elevation which is approx. at 1 km above ground. We do see the main storm formed in the ensemble and there is a good match between observed and analyses hook echo.



Horizontal cross-section of ensemble mean analyses of maximum updraft helicity ($m^2\ s^{-2}$), maximum vertical velocity ($m\ s^{-1}$) and KOUN reflectivity (dBZ) at 22:05 UTC.

Future Work Meso/Conv Data Assimilation

- Collaboration with NCAR/GSD to test various cycling methods on June 2009 V2 cases (Wheatley)
- Beginning work on MCS cases (Wheatley and Sobash)
- EnKF version of Gao and Stensrud 8 May paper (Yussouf, Wheatley, Gao)
- Multi-microphysics EnKF analyses/forecasts for 5 June 2009 Goshen Co. V2 case (Yussouf)

Other Current/Future Work

- Impact from use of conservative thermodynamic variables to improve EnKF analyses
  (C. Potvin)

- LETKF applied to VORTEX2 data sets
  (T. Thompson)

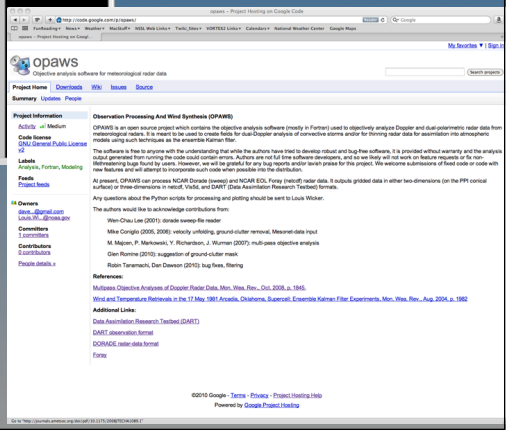
- Sensitivity study to determine sensitivity of supercells storms to uncertainty in environments
  (B. Belobraydich)

Scientific Impacts & Outreach

- Formal publications from NSSL WoF group (2010)
  - 4 papers published or in press
  - 2 more papers submitted
- Conference/Workshop (2010)
  - 10 papers
- Other
  - WoF web page (http://www.nssl.noaa.gov/projects/wof/)
  - OPAWS objective analysis software (http://code.google.com/p/opaws/)

WoF Web Page

Objective Analysis for Radar Data



Questions?